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(6) FRACTURE TOUGHNESS, FATIGUE AND CORROSION CHARACTERISTICS OF HIGH STRENGTH ALUMINUM EXTRUSIONS AND PLATE.

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ABSTRACT

All the material for the program, including 1/2-in. and 1-3/8-in. thick 7178-T651 and X7080-T7E41 plate and 11/16-in. and 3-1/2-in. thick 7075-T6510, 7075-T73510, 7178-T6510, and X7080-W510 and W511 extrusions, has been received. The compositions and tensile properties of the X7080 and 7178 plate were determined and indicate that these samples are suitable for use on the contract effort; fracture toughness, fatigue and corrosion specimens are being prepared. Following an aging study, the X7080 extrusions will be aged to the T75-type temper, and the evaluation of all the extrusions will get under way.

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QUARTERLY REPORT

FRACTURE TOUGHNESS, FATIGUE AND CORROSION CHARACTERISTICS OF 7075-T6510, 7075-T73510, X7080-T7510 AND 7178-T6510 EXTRUSIONS AND X7080-T751 AND 7178-T651 PLATE

I. Introduction.

Fracture toughness, fatigue and corrosion characteristics are among the most important properties in determining the suitability of material for many aerospace applications. The purpose of this contract is to provide such data for extrusions and plate of several alloys and tempers which appear potentially suitable for aerospace applications. The data obtained are not design or expected minimum values of the properties involved, but rather the results of tests of representative lots of material. As such, the data should be interpreted as representative values rather than statistically reliable average or minimum values of the properties involved.

This report summarizes the progress during the second quarter of the contract, from June 27 to September 27, 1967.

II. Material.

All materials have been received; the specific items are listed below.

Product	Alloys and Tempers Received
1/2-in. and 1-3/8-in. thick plate	7178-T651; X7080-W51
1/2x16-in.* integrally stiffened extruded panel	7075-T6510; 7075-T73510; 7178-T6510; X7080-W510
3-1/2x7-1/2-in. extruded bar	7075-T6510; 7075-T73510; 7178-T6510; X7080-W511

* Actual thickness is 11/16 in.

The 1/2-in. and 1-3/8-in. thick X7080-W51 plate was aged to the T7E41 temper at Alcoa Research Laboratories (See Section IV, Progress). An aging study will be conducted on the X7080-W510 and W511 extrusions in the two cross-sections to determine the proper aging treatments for this product, and then the W51X samples will be aged to the T75-type temper.

The results of the chemical analyses of the plate samples are given in Table I. The compositions were within limits, except that the chromium content of the analyzed pieces from the 1-3/8-in. 7178-T651 plate was 0.01 per cent below the minimum value. Since both the 1/2-in. and 1-3/8-in. samples were fabricated from the same ingot, and both the melt from which the ingot was cast and the 1/2-in. plate were within chemical composition limits, it is assumed that the slightly low chromium content of the thicker plate is representative of the expected point to point variation in composition of fabricated products. Such minor differences would have no effect on the properties of the samples.

III. Test Program.

Test specimens and procedures are as described in the First Quarterly Report, dated July 15, 1967, with the following exceptions:

1. The nominal-sized 1/2x16-in. integrally stiffened extruded panels actually have an 11/16-in. thick base and 1/2-in. thick ribs. This requires that round rather than sheet-type tensile specimens be taken from the base, as shown in Fig. 1. Additional specimens will be taken from the ribs; these will be sheet-type specimens and some will be of the

full thickness of the ribs while others will have 0.020 in. machined from the surface to illustrate the effect of surface machining on tensile properties.

2. Notched bend fracture-toughness specimens from the 1/2x16-in. integrally stiffened extruded panels are 11/16-in. thick (full base thickness) by 1-1/2-in. wide by 7-in. long, with a crack length of 3/4 in. rather than the smaller size indicated based upon the smaller nominal thickness. Also, the short-transverse fracture-toughness specimens from the 3-1/2x7-1/2 in. bar will be of the design in Fig. 2, slightly modified from that shown in the report dated July 1, 1967, to permit adequate chevron notching.
3. The axial-stress fatigue specimen with $K_t = 3$ which is being used in this program is shown in Fig. 3. It is identical with the sharply notched specimen with $K_t = 12$ (Fig. 5b; First Quarterly Report), except for the greater notch depth and milder notch root radius. This geometry was used in previous (non-contractual) programs, and compatible data for other materials will be available for comparison.
4. A thinner center-notched fatigue specimen, shown in Fig. 4, has been developed for use in determining fatigue crack propagation rates of the 1/2-in. thick samples. The 1/2 and 3/4 in. specimens have identical test sections, except for thickness.

IV. Progress During Past Quarter.

As indicated in the First Quarterly Report, alloy X7080 has not previously been produced as plate and extrusions, and some development work (at the Contractor's expense) is necessary to arrive at procedures suitable for commercial production of the alloy. The

tensile properties of the original plant-aged 1-3/8-in. thick X7080-T7E41 plate were lower than expected and indicated that the material as received was unsuitable for use on the contract because it would not have represented production quality. Therefore, a study was made of the aging characteristics of a sample of W51 plate from the same lot; Table II shows the tensile properties of the plate after four different aging treatments. Less severe aging treatments than that used by the plant resulted in higher strengths, typical of those expected in commercial production of this product. A proper aging treatment was selected and, with the approval of Mr. S. O. Davis, AFML Project Engineer, samples of 1/2-in. and 1-3/8-in. thick X7080-W51 plate from the same lot of material were aged to the T7E41 temper at Alcoa Research Laboratories for use on the contract.

The tensile properties of the ARL-aged 1/2 and 1-3/8-in. X7080-T7E41 plate to be used on the contract are shown in Table III, along with those of the 1/2-in. and 1-3/8-in. 7178-T651 plate. No minimum values have been established for X7080-T7E41 (equivalent to X7080-T751), but it appears that tensile strengths, yield strengths and elongations of these samples are near optimum levels. The tensile properties of the 7178-T651 plate are well above the specified minimum values in ASTM Specification B209-66.*

Also included in Table III are data for the 1/2-in. X7080 and 7178 plate with 0.020 in. machined from each surface to indicate the effect of this operation on the tensile properties. There was no indication of an effect for X7080, and for 7178, the strengths of the machined specimens were only about 1 per cent lower. It is concluded that the difference in tensile properties due to machining

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* ASTM Standards, Part 6, 1966.

is not significant. This variable is also to be studied in fracture-toughness and fatigue crack growth tests.

In previous axial-stress fatigue tests at Alcoa Research Laboratories, sheet-type specimens have been used for material up to 1/2-in. thick and round specimens have been used for material over 3/4 in. thick. No specimen appropriate to samples between 1/2 in. and 3/4 in. thick has been in use. The specimen shown in Fig. 5, which is identical with the usual round axial-stress fatigue specimen except for the flat grip ends, has been proposed, and a moderate program is underway (on materials other than contract samples) to ensure that the modified specimen geometry does not influence test results. Preliminary results indicate that this specimen will be suitable for tests of 1/2-in. thick plate and extruded panels.

The fracture-toughness specimens from the 1/2-in. and 1-3/8-in. 7178-T651 plate have been machined, and those from the 1-3/8-in. plate have been fatigue-cracked by cantilever bending at maximum nominal net-section bending stresses of 10 000 psi. Axial-stress fatigue specimens were machined from 1-3/8-in. thick 7178-T651 and X7080-T7E41 plate, and tests were begun. Also, fatigue crack propagation and corrosion specimens were machined from the 7178-T651 plate.

V. Program for Next Quarter.

It is expected that effort during the following quarter will be concentrated upon the completion of the evaluation of the properties of the plate materials and the initiation of tests of the extruded shapes. The following specific items are scheduled:

1. Chemical analyses and tensile tests of extruded materials will be completed.

2. An aging study will be made of the X7080-W510 and W511 extrusions to determine the proper aging treatment to produce the T7E42 (T7510 or T7511) temper, and the samples will be aged.
3. The machining of all tensile, fracture-toughness, and fatigue test specimens, except possibly some for the X7080 extrusions, will be completed.
4. The axial-stress fatigue tests of specimens from 1-3/8-in. thick 7178-T651 plate will be essentially completed, and some tests will be made of the other samples.
5. The notch-bend fracture toughness of the 1/2-in. and 1-3/8-in. thick plate will be completed.
6. The fatigue crack propagation tests of 7178-T651 plate will be started.
7. Machining of the corrosion specimens will be started. The initiation of the tests will be delayed until specimens for all samples are available.

The milestone chart in Fig. 6 may be considered to be applicable to the time when the X7080 extrusions are given the proper aging to the T7E42 (T7510 or T7511) temper.

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J. G. KAUFMAN

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VI. Tables and Figures.

TABLE I

CHEMICAL COMPOSITION OF PLATE SAMPLES
TO BE EVALUATED ON F33615-67-C-1521
(Tentative)

Alloy and Temper	Thickness, in.	ARL Sample Number	Element, Per Cent								
			Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti
X7080-T7E41	1/2	343260	0.14	0.20	0.92	0.32	2.01	0.00	0.00	6.22	0.03
	1-3/8	343259	0.14	0.19	0.92	0.32	2.01	0.00	0.00	6.25	0.03
	Nominal		----	----	1.0	0.35	2.25	----	----	6.0	----
	Limits (maximum unless range is shown)		0.30	0.40	0.50-1.5	0.10-0.7	1.5-3.0	0.12	----	5.0-7.0	0.20
7178-T651	1/2	340457	0.11	0.23	1.88	0.04	2.60	0.18	0.01	6.89	0.03
	1-3/8	340450	0.10	0.22	1.95	0.04	2.54	0.17	0.01	6.61	0.03
	Nominal		----	----	2.0	----	2.7	0.30	----	6.8	----
	Limits (maximum unless range is shown)		0.50	0.07	1.6-2.4	0.30	2.4-3.1	0.18-0.40	----	6.3-7.3	0.20

TABLE II

TENSILE PROPERTIES OF SOME 1-3/8-IN. THICK X7080 PLATE FOLLOWING VARIOUS AGING TREATMENTS

Aging Treatment	LONGITUDINAL			LONG TRANSVERSE			SHORT TRANSVERSE		
	Tensile Strength, psi	Yield Strength, psi	El. in 4D, %	Tensile Strength, psi	Yield Strength, psi	El. in 4D, %	Tensile Strength, psi	Yield Strength, psi	El. in 4D, %
ARL-A	71 300	64 400	14.5	71 300	63 600	12.1	69 700	59 800	6.0
ARL-B	71 500	64 800	14.8	71 400	63 600	12.4	70 000	60 400	6.0
ARL-C	69 100	61 000	14.6	69 000	60 000	12.6	67 800	57 200	6.2
ARL-D	65 600	56 200	15.5	65 600	55 400	12.9	64 200	52 600	6.8
-T7E41 (as received from plant)	61 000	50 300	15.0	61 100	50 100	13.0	60 100	47 600	6.0
-T7E41 (Aged at ARL from -W51)	67 900	60 200	14.5	68 300	59 600	12.5	67 100	56 300	7.0

Table II

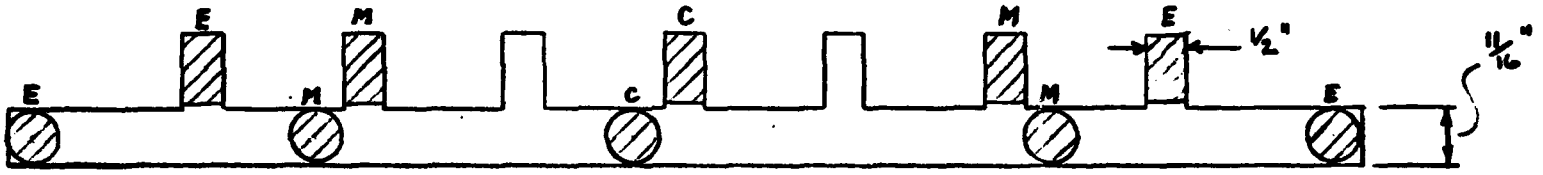
TABLE III

TENSILE PROPERTIES OF 1/2 AND 1-3/8 IN. PLATE SAMPLES
TO BE EVALUATED ON F33615-67-C-1521
(Tentative)

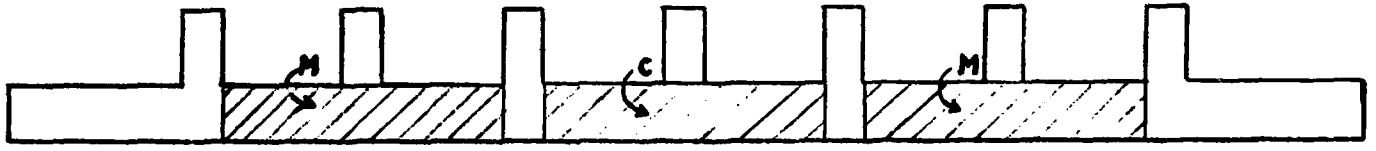
Alloy and Temper	ARL Sample Number	Thickness, in.	LONGITUDINAL			LONG-TRANSVERSE			SHORT-TRANSVERSE		
			Tensile Strength, psi	Tensile Yield Strength, * psi	Elong. in 2 in. or 4D, %	Tensile Strength, psi	Tensile Yield Strength, * psi	Elong. in 2 in. or 4D, %	Tensile Strength, psi	Tensile Yield Strength, * psi	Elong. in 2 in. or 4D, %
7080-T7351 (T751)	343260	1/2									
Original Surfaces			68 200	58 900	16.5	67 600	56 800	15.0	--	--	---
Machined Surfaces			68 300	59 100	16.0	--	--	--	--	--	---
	343259	1-3/8	67 900	60 200	14.5	68 300	59 600	12.5	67 100	56 300	7.0
7178-T651	340457	1/2									
Original Surfaces			88 800	83 400	14.5	88 500	78 800	11.0	--	--	---
Machined Surfaces			88 100	82 400	13.0	--	--	--	--	--	---
	340450	1-3/8	92 500	81 900	9.0	87 800	77 800	9.0	80 200	68 100	2.2

* 0.2 per cent offset.

C - Center M - Midway E - Edge



Longitudinal (Sheet-type and 0.357-in. Diameter Round)



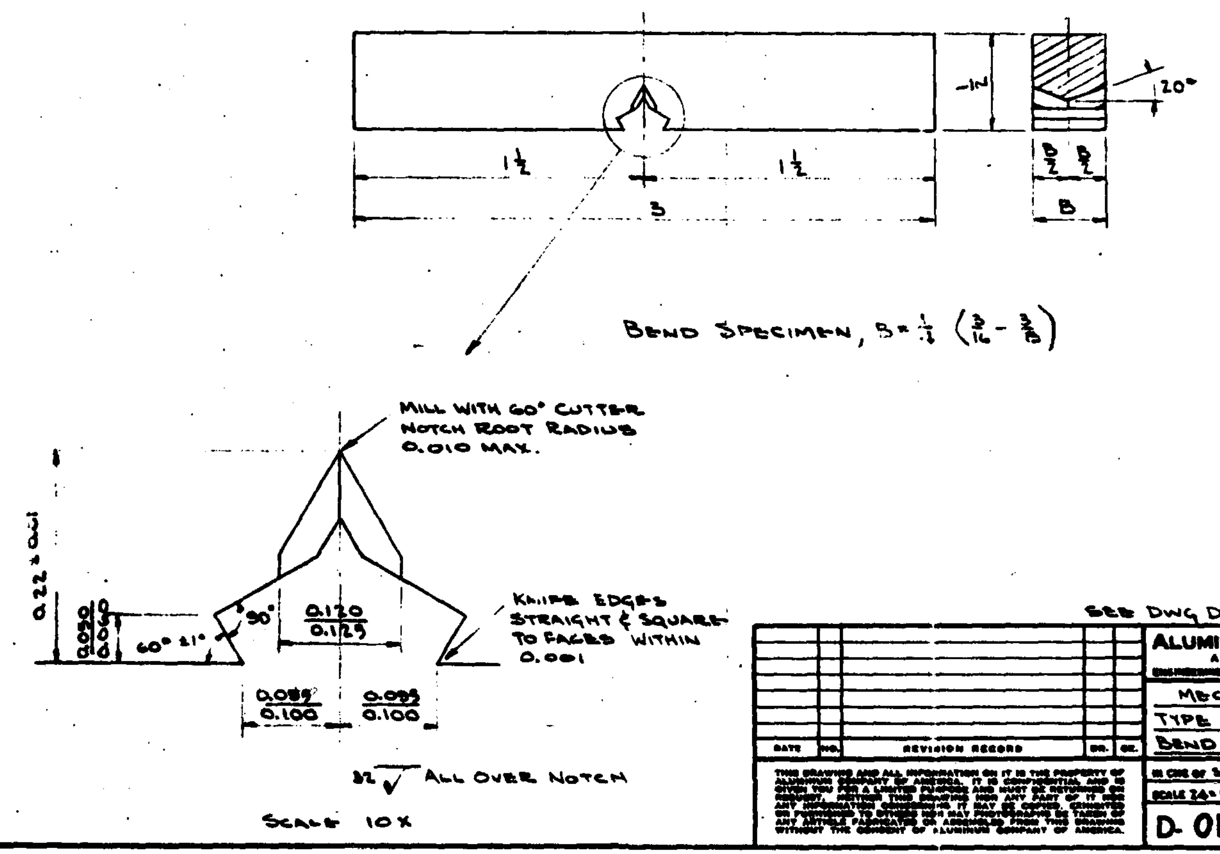
Long-Transverse (0.357-in. Diameter Round)

Fig. 1 Locations of Tensile Specimens in Extruded Integrally Stiffened Panels.

Fig. 1

D-011475-RK

BILL OF MATERIAL		
REF. No.	QUAN.	DESCRIPTION



SEE DWG D-010754 FOR TYPE 2-8 INC.

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ALCOA RESEARCH LABORATORIES
ENGINEERING DEPARTMENT — NEW KENSINGTON, PA.

MECHANICAL TESTING DIV.
TYPE I DEEP CRACK-NOTCH
BEND SPECIMEN FOR K_{Ic} TESTS

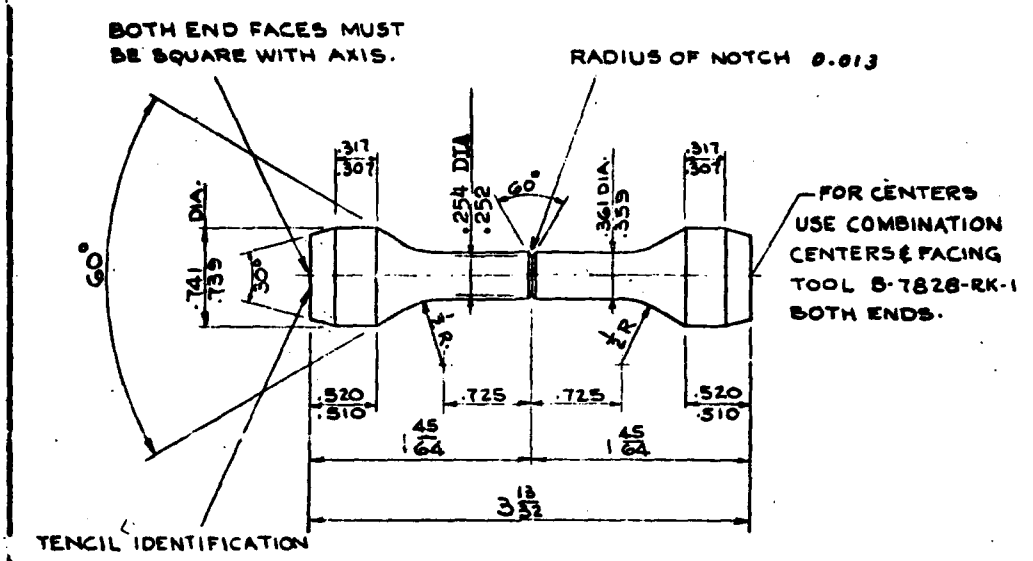
DATE	NO.	REVISION RECORD	DR.	CK.

IN CARE OF S. C. HUDDLESTON | DESIGN
SCALE 24=1-0 | DATE 9-6-67 | DRAWN R. MCCLELLAN
CHECK
APPR.

D-011475-RK

Fig. 2

L-8895-RK



SPLIT RING	L-7514-RK
TEMPLET	C-8896-RK

DATE	NO.	REVISION RECORD	DR	CK

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MECHANICAL TESTING DIV.

300 ROOT DIA. TAPERED SEAT DIRECT TENSION COMPRESSION - NOTCHED SPECIMEN

IN CHG OF S.C.H.	DESIGN
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L-8895-RK	CHECK
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Fig. 3

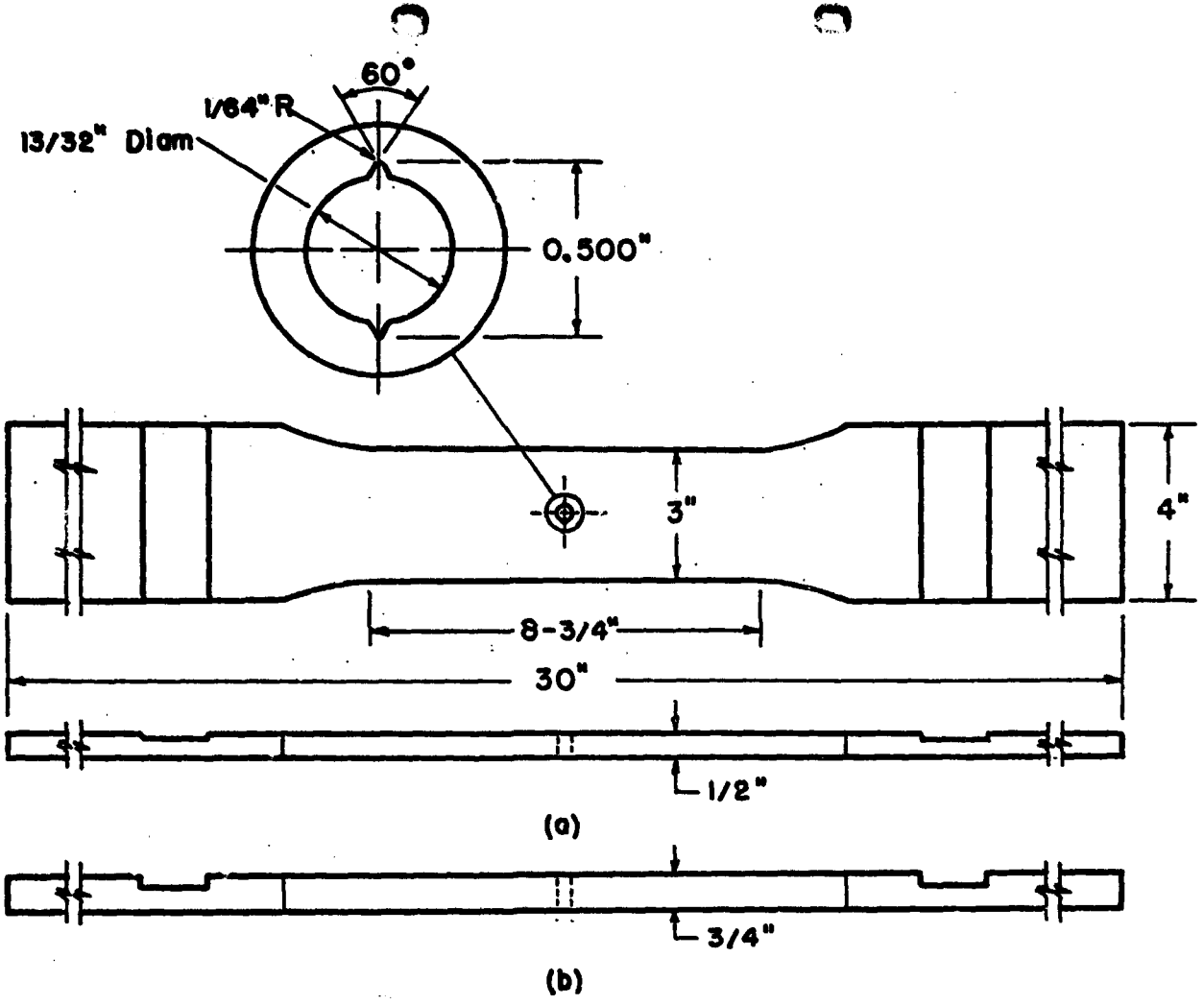

Fig. 4 CENTER-NOTCHED FATIGUE SPECIMENS

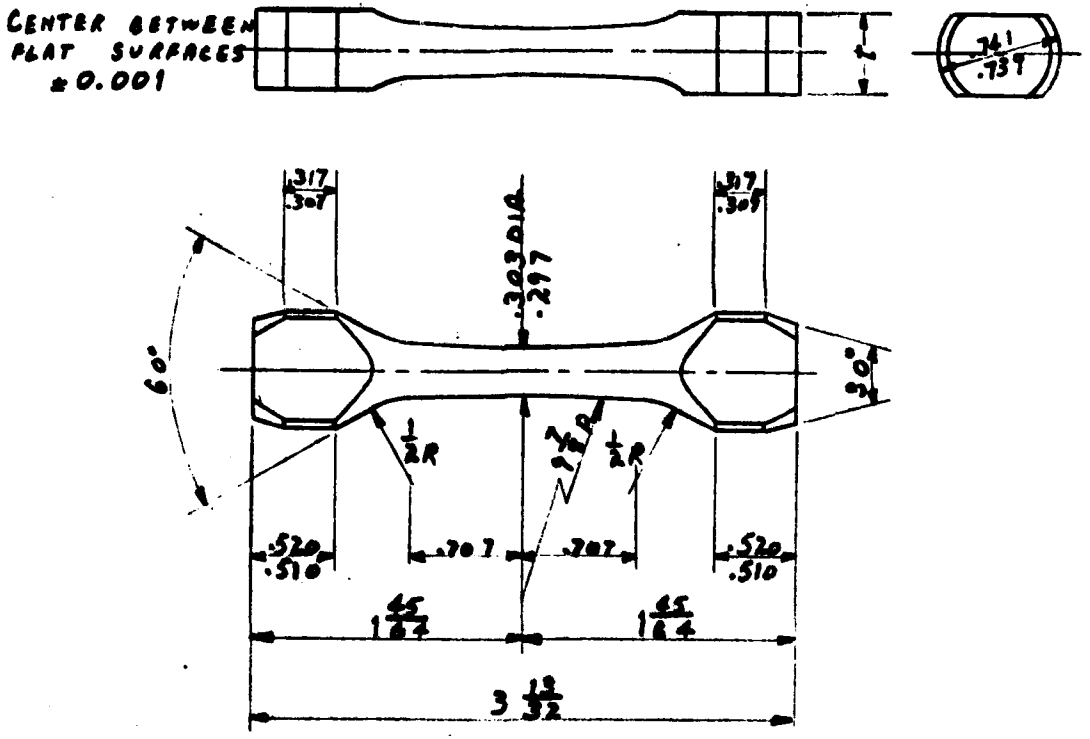

Fig. 5 Axial-Stress Fatigue Specimen from Material 1/2-in. to 3/4-in. Thick.

Fig. 5

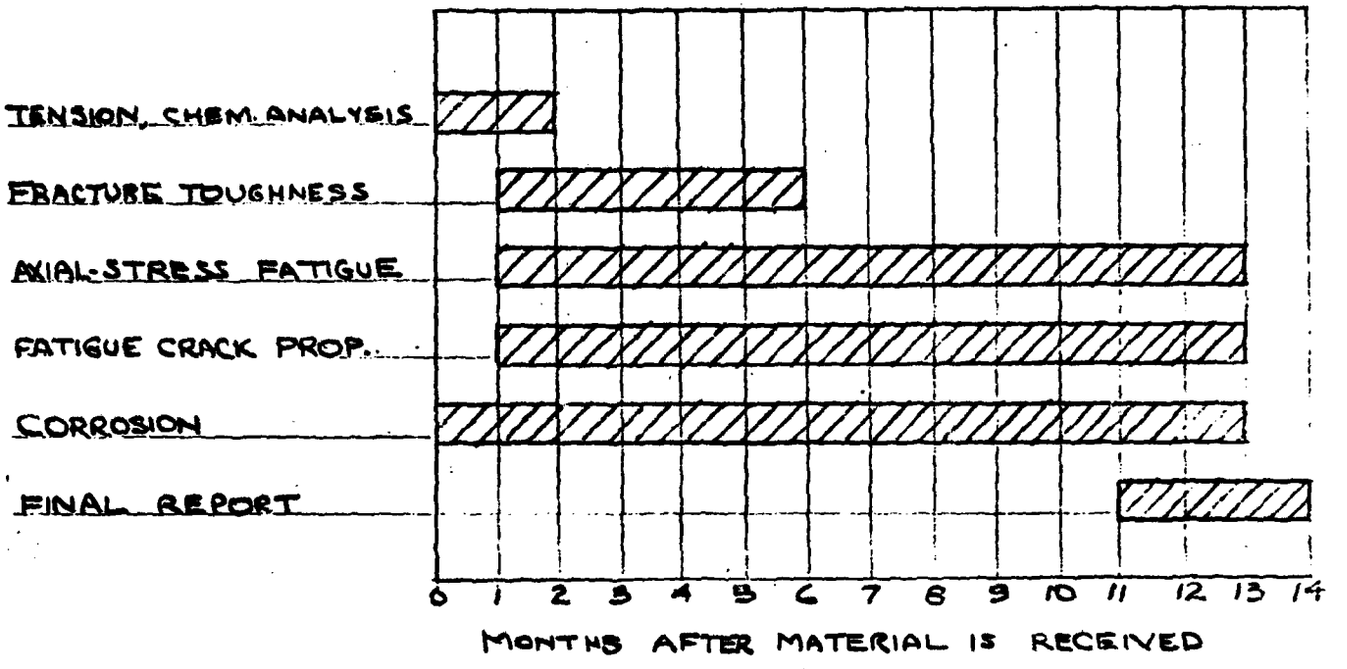

Fig. 6 Milestone Chart for Program on Fracture Toughness, Fatigue and Corrosion Characteristics of Aluminum Alloy Plate and Extrusions.

FIG. 6